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TERMINAL BALLISTIC CHARACTERIZATION OF A 20mm PLASTIC FRANGIBLE PROJECTILE

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TERMINAL BALLISTICS BRANCH
GUNS, ROCKETS AND EXPLOSIVES DIVISION

FEBRUARY 1975

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Tests were conducted to determine the terminal ballistic characteristics of a 20mm plastic frangible projectile when fired into loose Eglin sand. The distribution and velocities of reflected platelets are presented for various projectile impact angles and impact velocities.

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PREFACE

The tests documented in this report were performed as an in-house effort under Project 25490305 for the Air Force Armament Laboratory (DLDT), Armament Development and Test Center, Eglin Air Force Base, Florida 32542. The tests were initiated in March 1974 and completed in November 1974.

Project Engineer for this effort was 1Lt Jeffrey D. Rawls (DLDT). Mr. Robert F. Brandt (DLDT) assisted in the design of the test setup and SSgt William Holmes (DLDT) assisted in the numerous test firings.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

GERALD P. D'ARCY, Colonel, USAF
Actg Ch, Guns, Rockets & Explosives Div

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SECTION I

INTRODUCTION

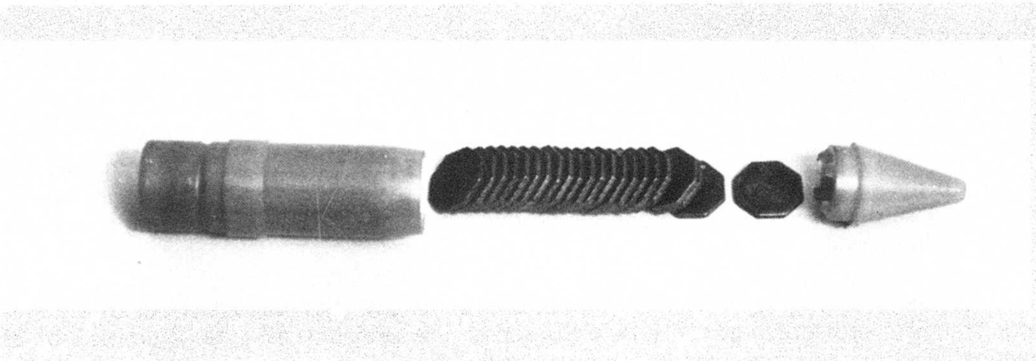
The Air Force has a very limited number of strafing test ranges for the 20mm machine gun due to the requirement for large safety zones behind the target area to contain long ricochets. Use of a frangible projectile would make smaller ranges usable if long ricochets could be eliminated.

This project was designed to determine the terminal ballistics characteristics of a 20mm plastic frangible projectile against loose Eglin sand. The projectile (Figure 1) consists of 29 octagonal steel platelets enclosed in a molded nylon shell (Reference 1). The projectile shell is designed to fracture upon target impact and to disperse the enclosed platelets. Reflected platelet distribution and velocity are determined as a function of impact velocity and impact angle.

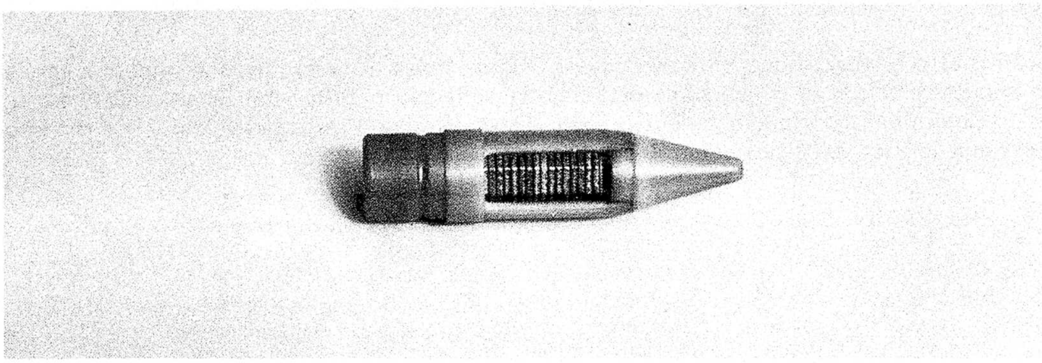
This effort was divided into two phases. Phase I was to determine the impact angles and the impact velocities at which some platelets are reflected off the sand target, and Phase II was to determine the platelet reflected angle distribution and reflected velocity for the impact angles and impact velocities determined in Phase I.

Reference:

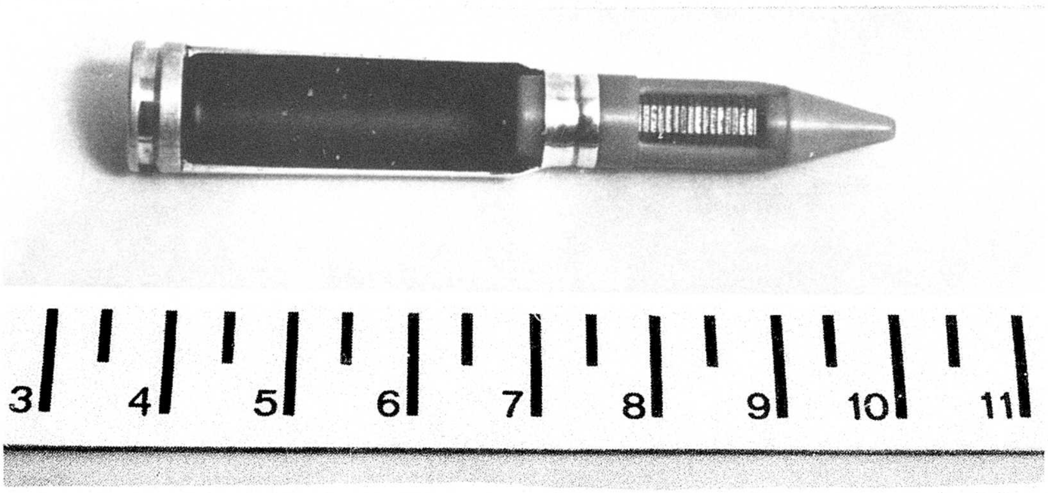
1. Air Force Armament Laboratory Technical Report AFATL-TR-74-53, Development of a 20mm Plastic Frangible Projectile, February 1974, UNCLASSIFIED.



a. Exploded View



b. Frangible Projectile Assembly



c. Cartridge Assembly

Figure 1. 20mm Frangible Cartridge

SECTION II

TECHNICAL DISCUSSION

1. TARGET PREPARATION

Typical Eglin Air Force Base sand meets the requirements for land strafing ranges as given in AFM 50-46, "Maintenance of Test Ranges" ("Maintain a soft level impact area . . . Soft, sandy soil is recommended . . . Disc harrow the area frequently and thoroughly to aid projectile absorption by the ground . . . Clear area in the center should be filled with soft, sandy soil to a depth of at least 18 inches in the immediate impact area".) An area on the test range approximately 1 meter wide by 3 meters long was cleared of grass, roots, and other debris. Each day the area was spaded loose to a depth of 0.30 meter, then graded level by hand before each shot. The moisture content of the soil was not measured since moisture content was not mentioned in AFM 50-46, although obvious differences in moisture content of the sand (i.e., very wet sand versus very dry sand) were recorded on a daily basis.

2. TESTS - PHASE I

The test setup for Phase I is shown in Figure 2. A single projectile was fired from the Mann barrel through the velocity screens and yaw paper to the target. The yaw paper was used to determine whether or not the projectile was oscillating in-flight. (Oscillating projectiles were not considered in the discussion.) A single sheet of fiberboard covered with kraft paper was used as a witness panel to determine the number and direction of any reflected platelets. The procedure followed after each shot was to (a) recover and count the platelets remaining in the sand, (b) recover and count the platelets on the ground between the sand target and the witness panel, and (c) count the holes made in the witness panel by penetrating platelets.

3 PHASE I RESULTS

At a 30-degree incidence impact angle, 13 projectiles were fired at velocities between 994 meters per second (3260 fps) and 346 meters per second (1135 fps). The impact velocity for each shot is shown in Table 1. All of the projectiles fragmented upon impact and all of the platelets from each projectile were found buried in the sand.

At a 20-degree incidence impact angle, 49 projectiles were fired at velocities between 999 meters per second (3277 fps) and 278 meters per second (912 fps). The impact velocity for each shot is shown in Table 2. Each projectile fragmented upon impact except one which impacted at 278 meters per second (912 fps). This projectile was not reflected off the sand. The low impact velocity is probably the reason for the projectile not fragmenting. The three projectiles indicated in Table 2 had platelets reflected off the sand onto the witness panel. Other projectiles were fired under similar conditions near those velocities, but no platelets were reflected from these projectiles.

4. TESTS - PHASE II

The first step of Phase II was to design a system to measure the time-of-flight of the reflected platelets. Dahlgren witness screens were used because they could respond to more than one platelet penetration per shot. A schematic of the Dahlgren screen is shown in Figure 3.

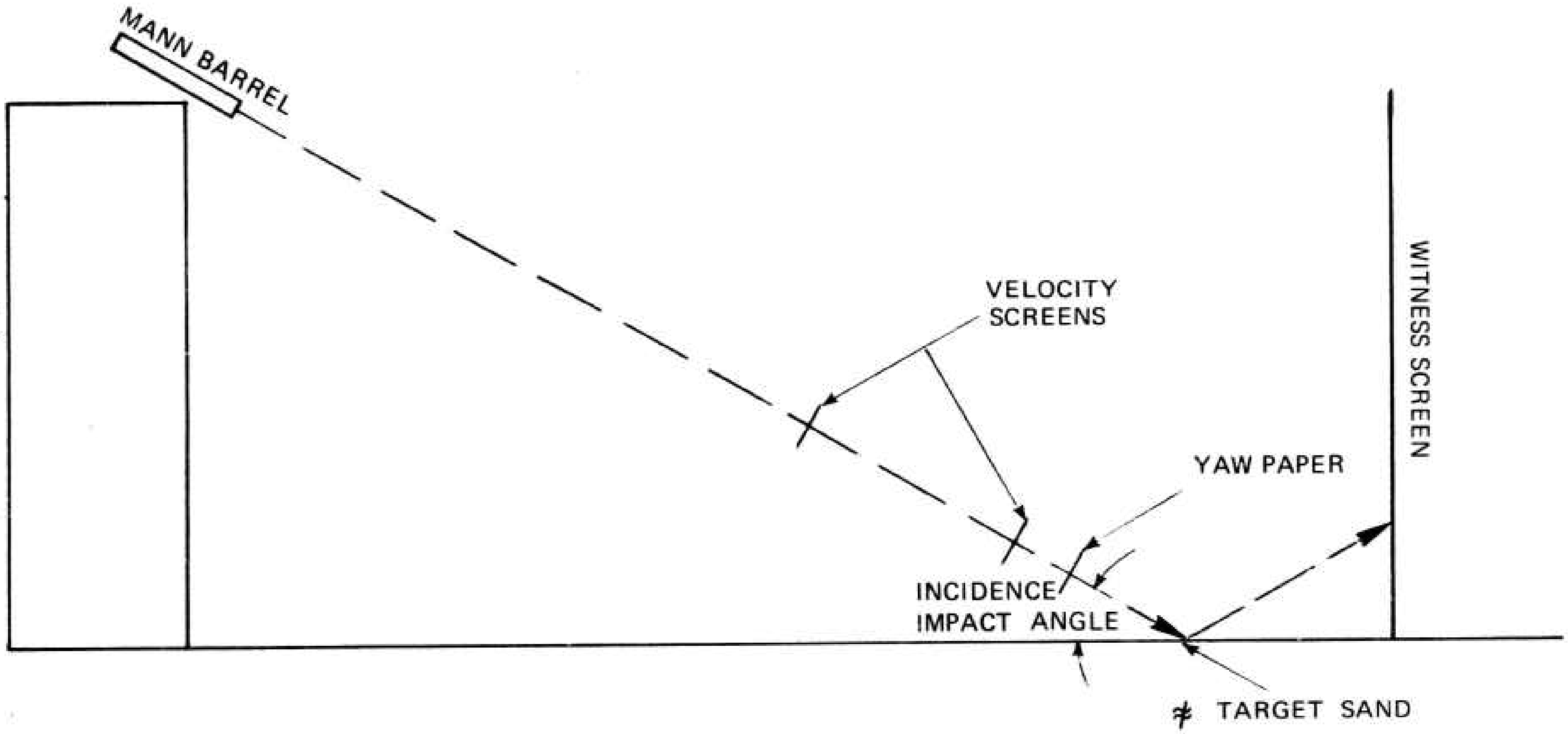


Figure 2. Phase I Test Arrangement

TABLE 1. SHOT RECORD OF PROJECTILES FIRED AT 30-DEGREE IMPACT ANGLE INTO SAND TARGET

Shot Number	Impact Velocity (meters per second)	No. of Reflected Platelets
021	994	0
022	982	0
020	981	0
040	560	0
039	541	0
041	512	0
037	453	0
038	452	0
032	442	0
031	437	0
034	434	0
033	421	0
035	346	0

TABLE 2. SHOT RECORD OF PROJECTILES FIRED AT 20-DEGREE IMPACT ANGLE INTO SAND TARGET

Shot Number	Impact Velocity (meters per second)	No. of Reflected Platelets
067	999	0
068	996	0
069	993	0
113	721	0
112	717	0
111	709	0
110	702	0
095	608	0
097	600	0
094	599	0
096	585	0
072	554	2
081	552	0
080	541	0
079	529	1
076	520	0
077	513	0
074	503	0
078	495	0
070	488	2
071	480	0
075	479	0
114	476	0
073	469	0
115	456	0
084	454	0
090	448	0
085	443	0
089	415	0
082	414	0
083	414	0
086	413	0
088	411	0
087	395	0
091	373	0
092	367	0
093	365	0
099	334	0
101	334	0
104	331	0
108	299	0
109	297	0
098	289	0
105	285	0
107	282	0
102	278	Did not fragment

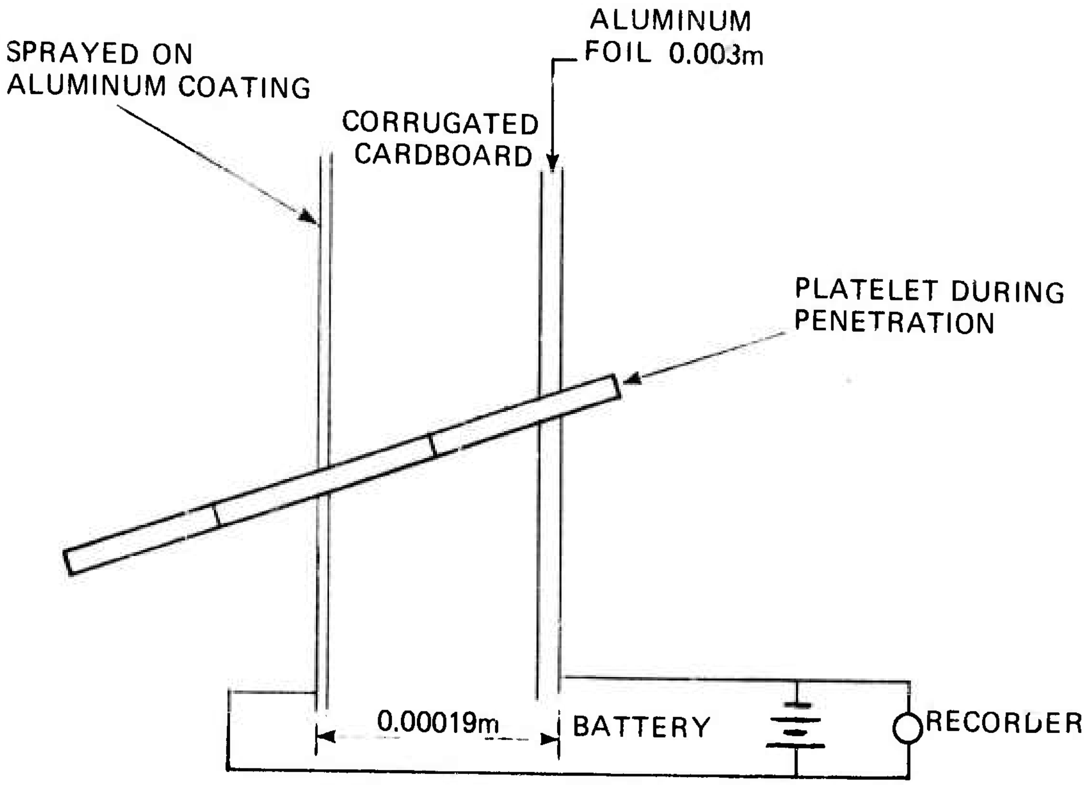


Figure 3. Schematic of Dahlgren Screen (Side View) Not to Scale

The Dahlgren screen is a make-circuit device. When a metal platelet passes through the cardboard it temporarily shorts the battery by connecting the sprayed aluminum coating on the front with the aluminum foil on the back. The short causes a temporary voltage drop which is seen by the recorder. After the platelet has passed through the screen, the circuit is reopened and the system quickly returns to its original state.

In order to determine the best Dahlgren screen setup, the test setup shown in Figure 4 was used. One set of screens was placed 1.50 meters (Station 1) from the Break Paper, and one set of screens was placed 3.00 meters (Station 2) from the Break Paper. Each screen was connected to one channel of an analog recorder as shown in Figure 5. Each time a platelet penetrated the screen, a signal was recorded on the analog tape. After a shot with reflected platelets, probable lines-of-flight were drawn from the sand target through the holes in the Station 1 screens to the holes in the Station 2 screens. In most cases, the three holes made by each platelet were aligned in a straight line. Hole patterns made by groups of platelets were observed at Station 1. These hole patterns were repeated at Station 2. These observations indicated that no drastic change in direction occurred between the sand target and Station 2. Also, the times measured between the Break Paper trigger signal and the subsequent signals made when the platelets penetrated the Dahlgren witness screens were compared. The calculated velocity (time-of-flight of a platelet divided by the distance between the Break Paper and the Dahlgren screen) was the same for both stations.

The target area was 0.10 meter in front of the Break Paper so that the platelets would be leaving the sand as they passed the Break Paper. All of the platelets were assumed to leave the Break Paper simultaneously; however, this assumption may not be strictly true. The greater the distance between the Break Paper and the witness screen, the less effect an error in this assumption will have on the time-of-flight measurements. Conversely, a very large distance would not give a very accurate measurement of the initial reflected velocity of each platelet. Therefore, the 3.00-meter witness screen distance was chosen for the Phase II firings.

Figure 6 shows the final test setup used to measure the distribution and time-of-flight of the reflected platelets. The frame network in the lower left-hand corner of the figure is the impact velocity measuring system and the yaw paper holder. The wooden frame and paper in the center of the figure is the semiburied Break Paper. The set of Dahlgren witness screens is in the rear.

Figure 7 is a schematic of the setup shown in Figure 6. The projectile aim point was 0.10 meter in front of the semiburied Break Paper and along the centerline of the witness screen. The angles shown define the zones covered by the Dahlgren witness screens.

Witness paper was extended 0.70 meter above the top of the Dalhgren screens to guarantee that any platelets going over the Dalhgren screens would also be scored. The paper extended the entire coverage to a vertical angle at 45 degrees.

The Dahlgren witness screens were arranged in eight zones as shown in Figure 8. Zones 40, 30, and 20 represent zones of 10-degree vertical angles as measured from the break screen (Figure 7) for left of the shot centerline. Zone 10 represents a 6-degree vertical angle. Zones 50, 60, 70, and 80 represent similar divisions for the right of the shot centerline.

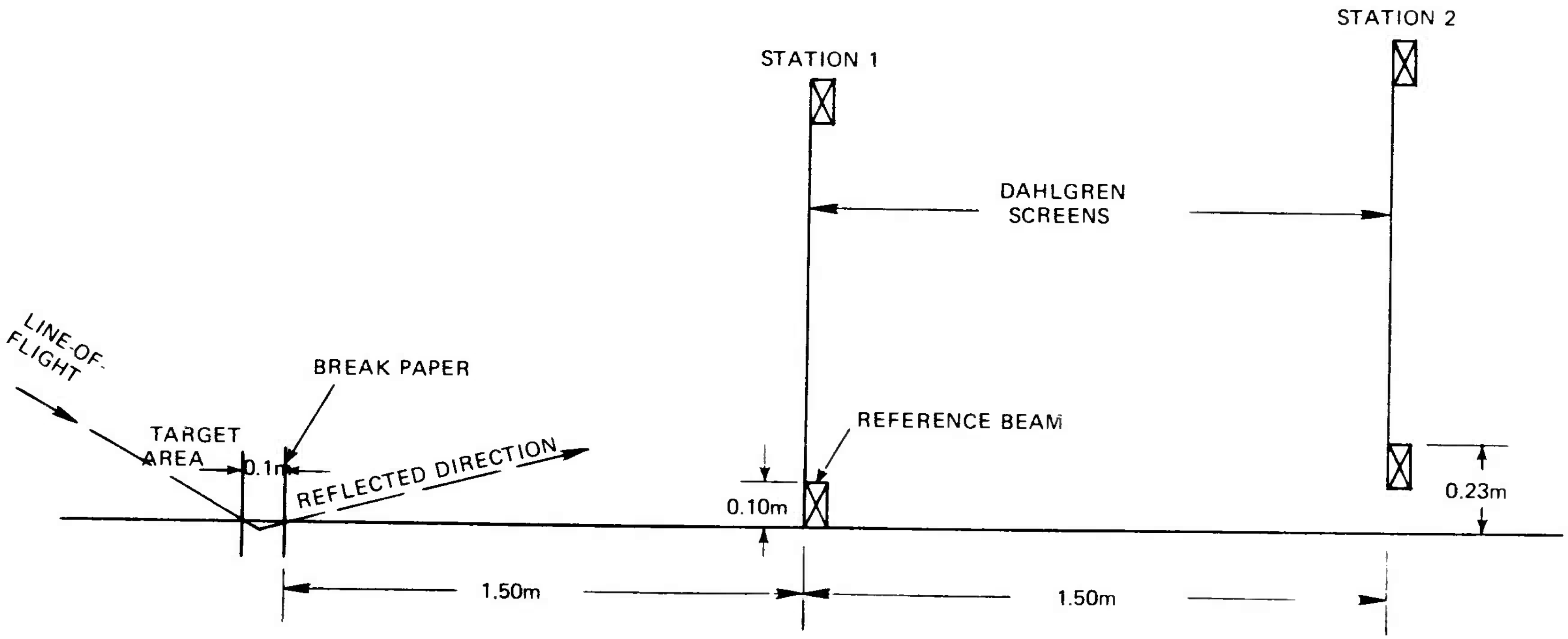


Figure 4. Initial Test Setup for Phase II Firings

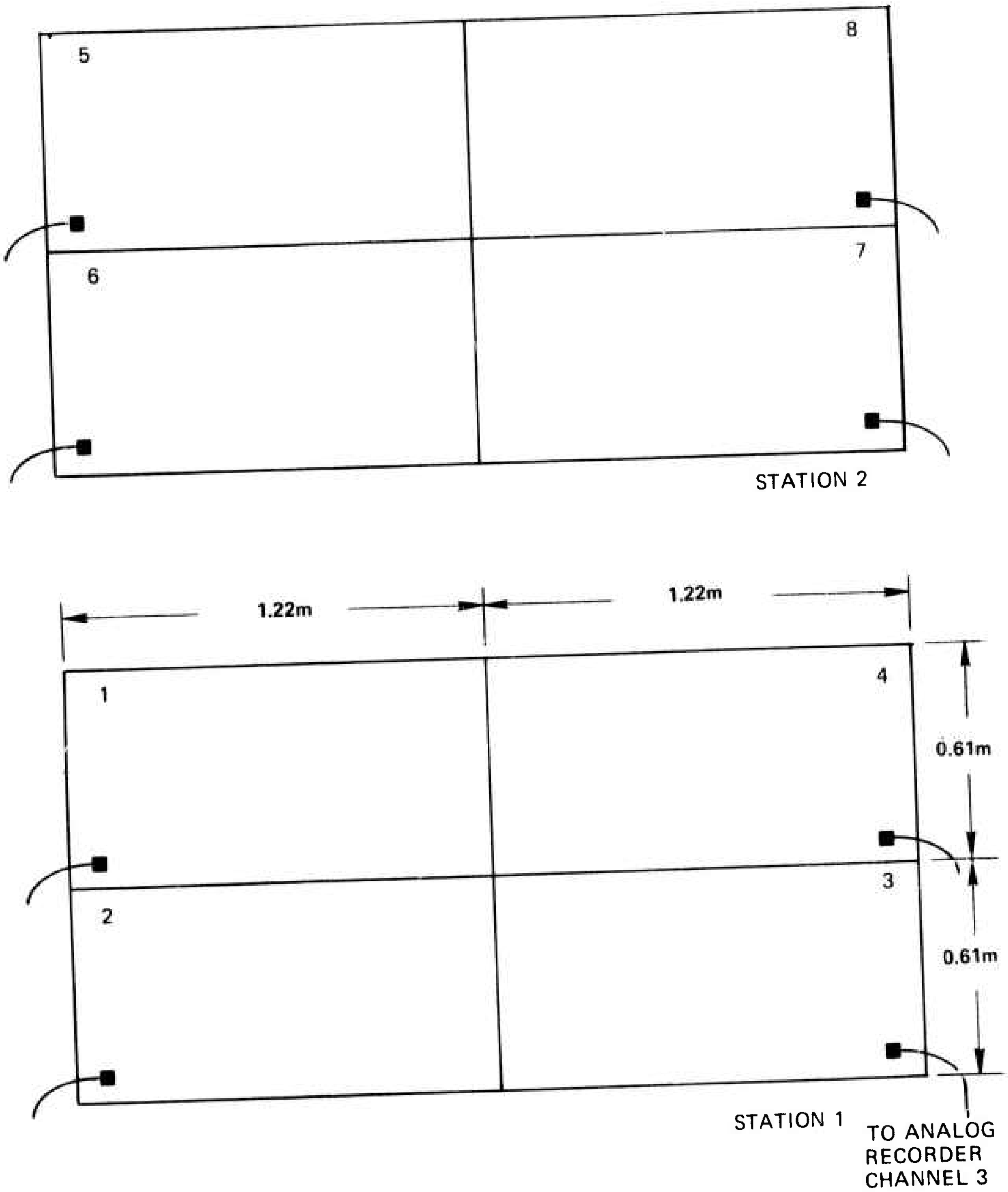


Figure 5. Dimensions of Dahlgren Screen (Front View)

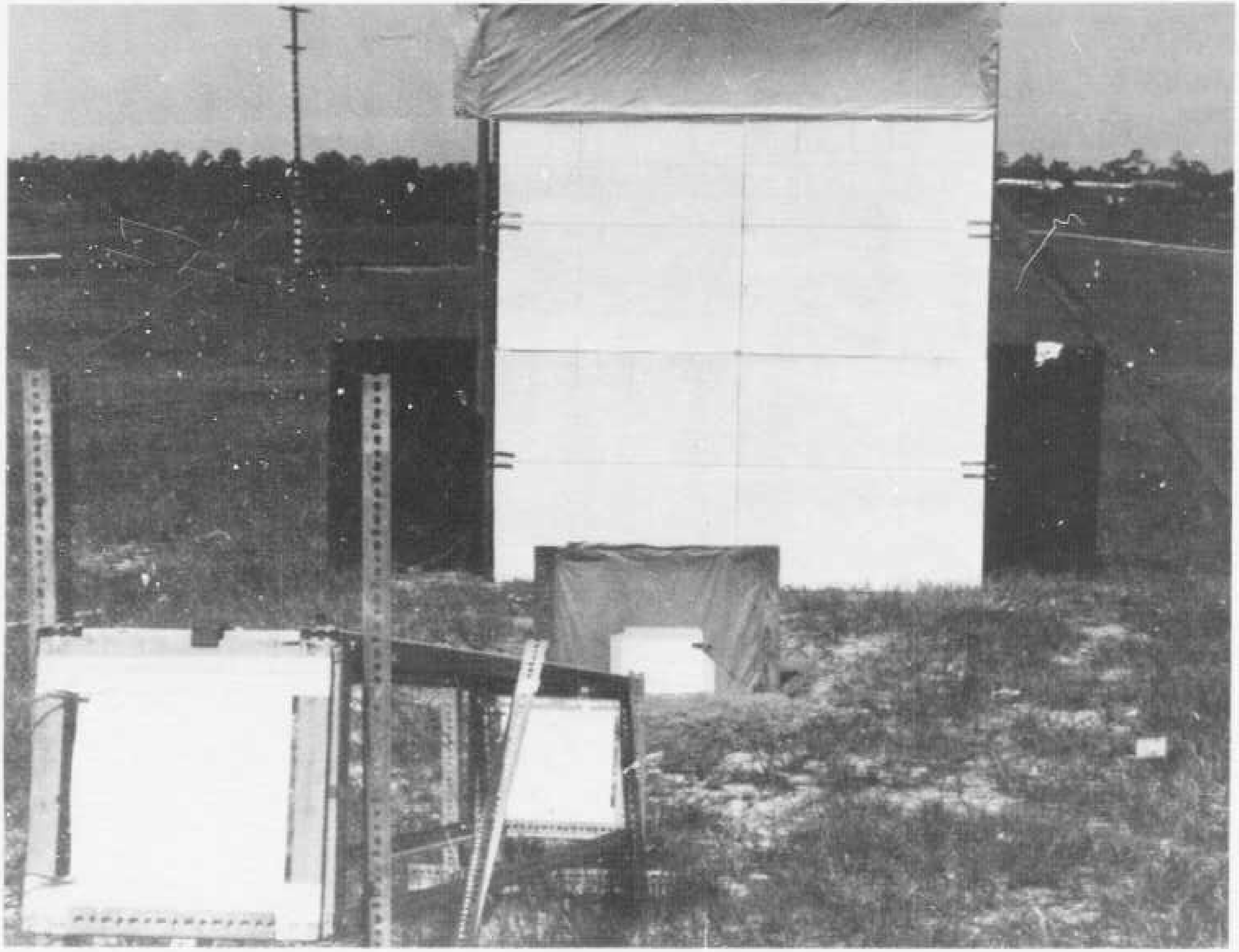


Figure 6. Test Setup for Determining Reflected Platelet Velocity and Distribution

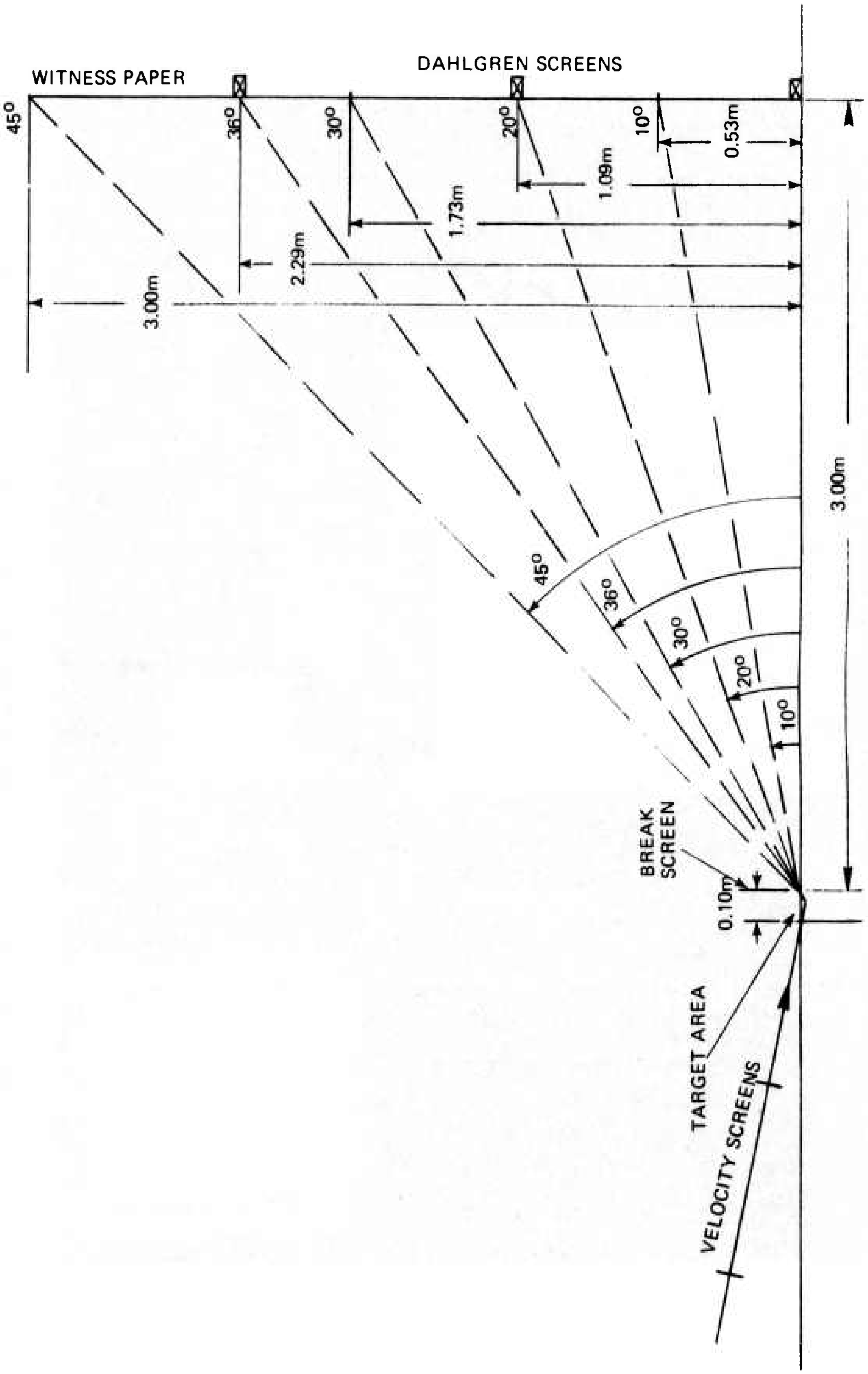


Figure 7. Phase II Test Setup

Each Dahlgren screen and the Break Paper were connected to one channel of an analog recorder. The reflected platelets would break the paper, then each platelet penetrating a Dahlgren screen would be recorded on the analog tape. Time-of-flight was determined by measuring the time between the break signal and the platelet penetration.

Each Dahlgren screen/zone was divided with chalk lines into four panels and numbered as shown in Figure 9. The first three panels numbered from the shot centerline (e.g., 51, 52, 53) represent 5-degree horizontal zones. The fourth panel (e.g., 54) represents a 7-degree horizontal zone.

5. PHASE II RESULTS

Fifty projectiles were fired at a 10-degree incidence impact angle at velocities between 988 meters/second (3241 fps) and 291 meters/second (954 fps). The impact velocity for each shot is shown in Table 3.

After each shot, the platelets that were not reflected off the sand were recovered. Figure 10 shows a witness screen after a shot. The number of platelet holes in each panel are shown in Table 3. The maximum and minimum reflected platelet velocities for each zone receiving a hit are shown in Table 4. These velocity calculations are described in Appendix A.

Only one of the five projectiles impacting below 313 meters/second (1027 fps) fragmented upon impact. The other four were reflected intact off the sand. An X indicates the panel penetrated by the ricochet projectile. The reflected velocity of each projectile is shown in Table 3.

Calculations were made for the maximum altitude and maximum horizontal range attained by the fastest reflected platelet at 20 and 30 degrees. The results of these calculations are shown in Section III.

6. FIRINGS AGAINST WATER TARGETS

Some firings were made against water at incidence impact angles of 30 and 20 degrees. All of the projectiles fragmented after impact with the water with no significant platelet reflections occurring.

AFM 50-39 cites flying safety problems, such as poor depth perception and loss of horizon, as reasons for not recommending water strafing ranges. In addition, inquiry to 33rd TAC Chief of Operations revealed no known water strafing ranges currently in use. Therefore, testing against the water target was discontinued.

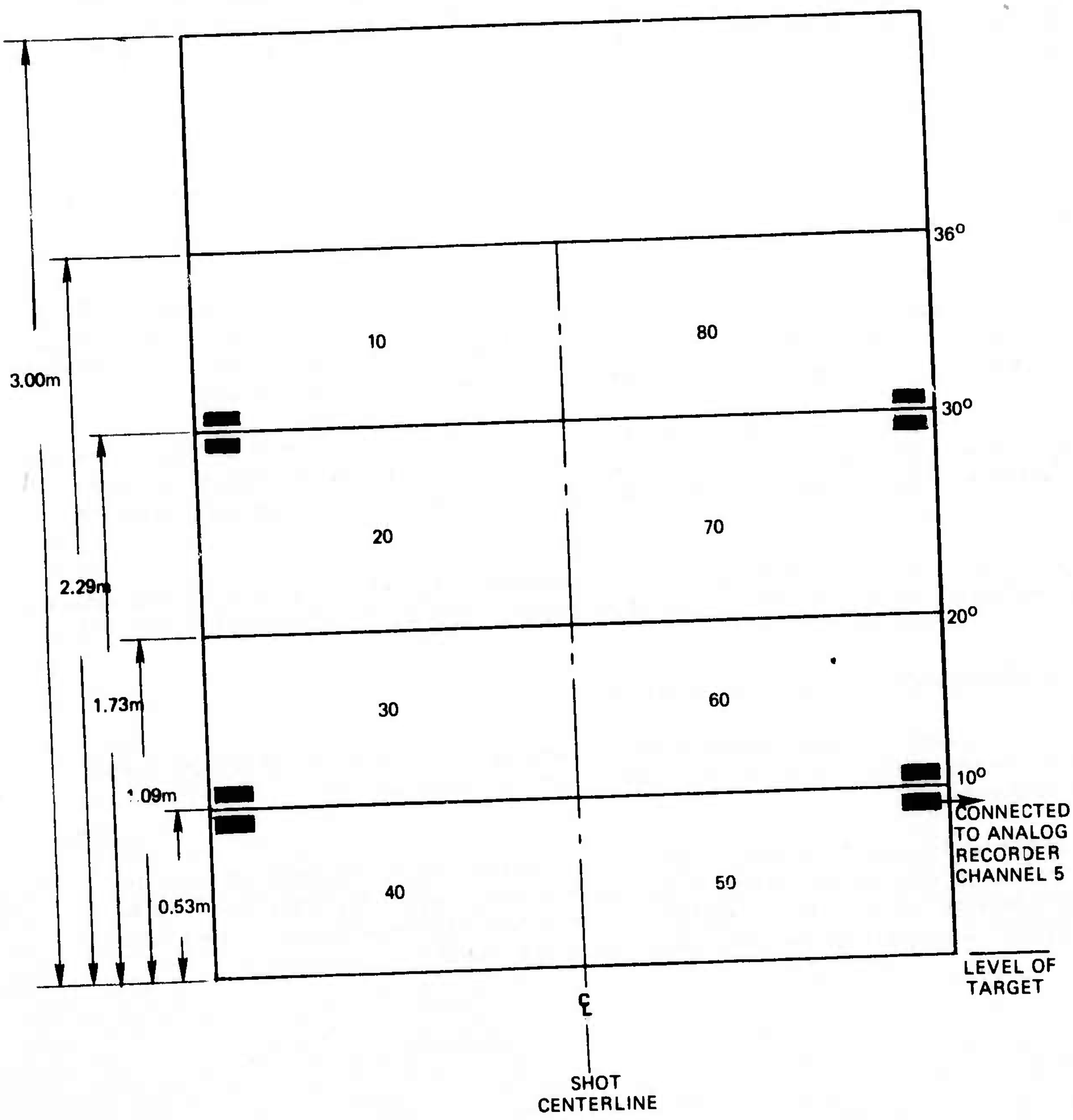


Figure 8. Witness Screen/Zone Identification

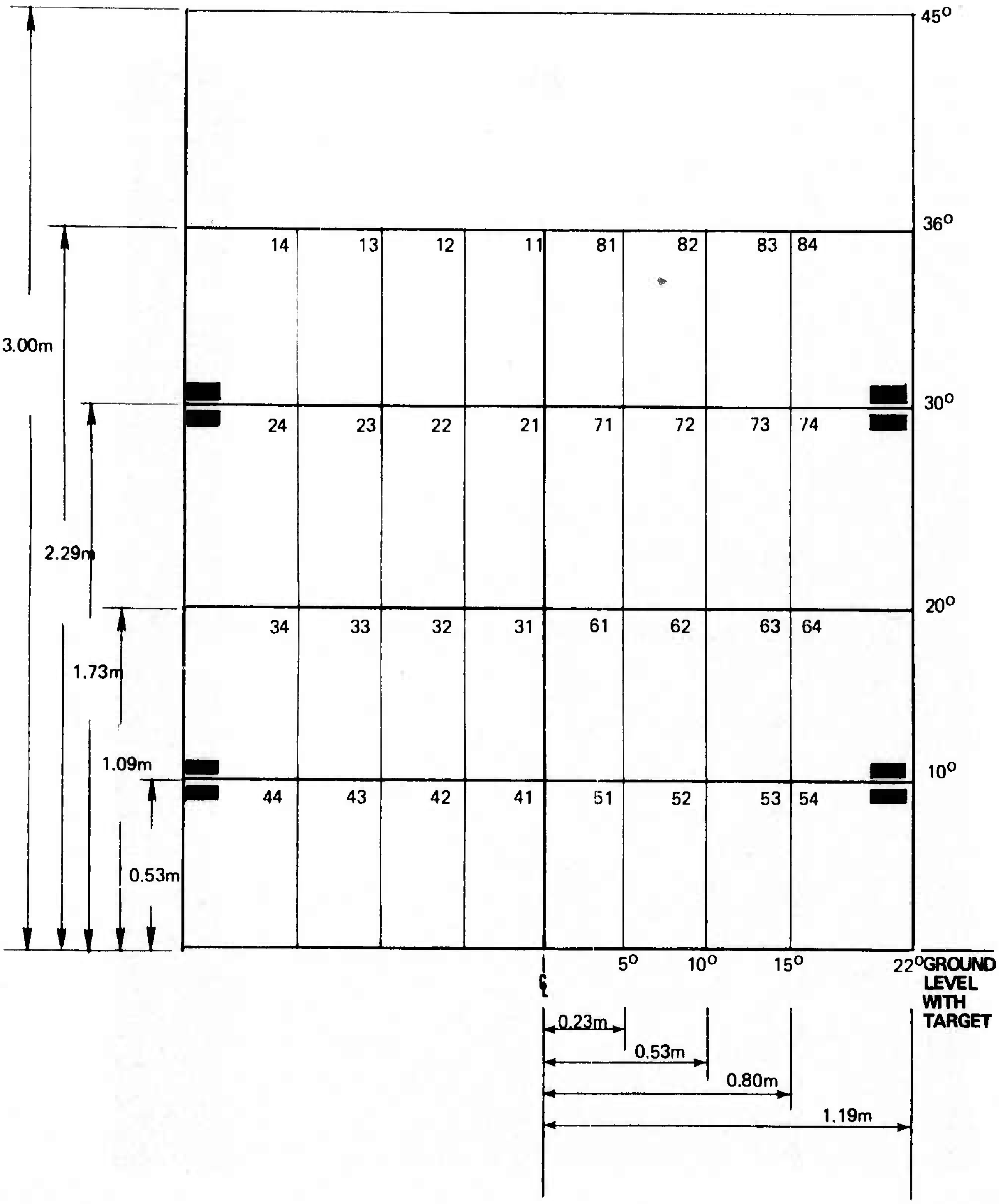


Figure 9. Witness Panel Identification

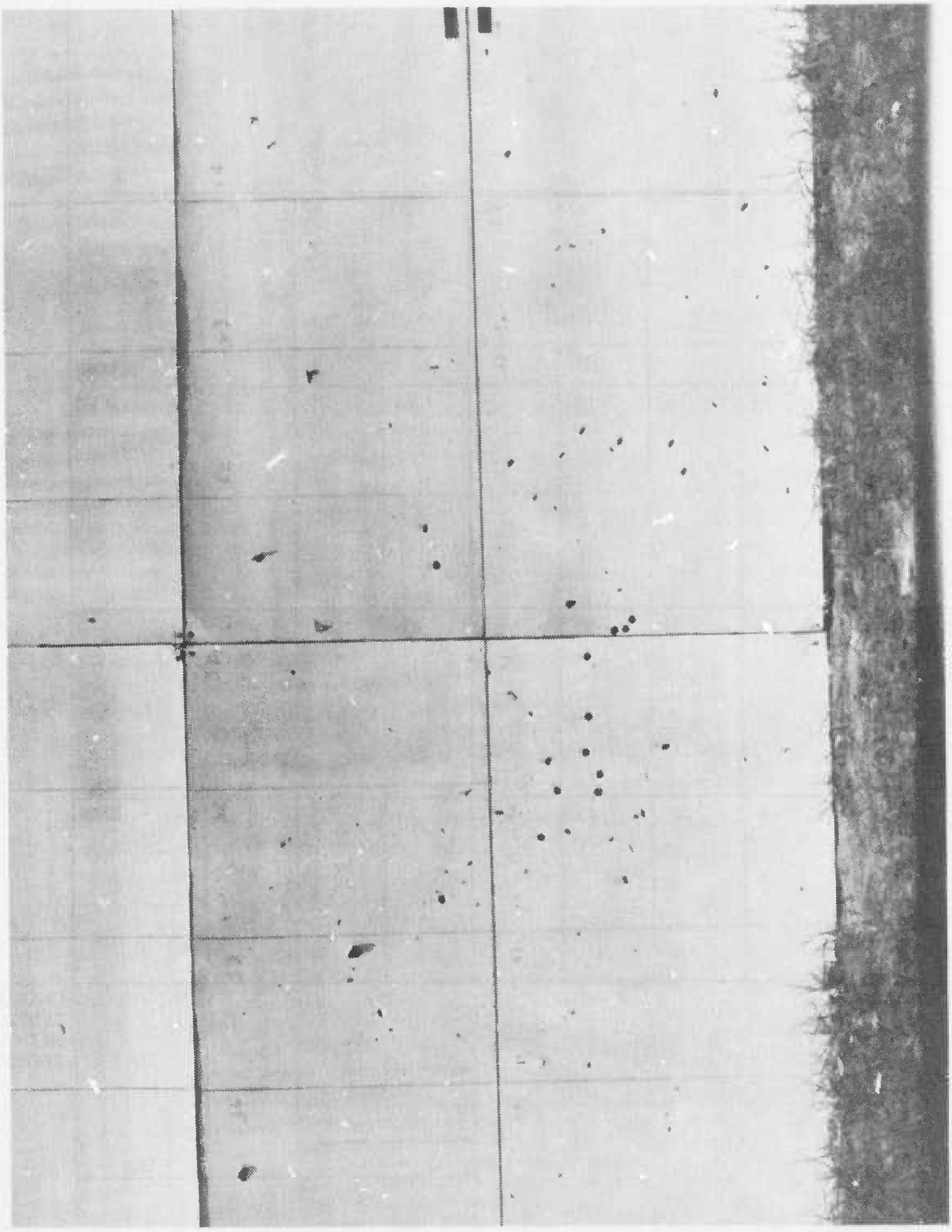


Figure 10. Dahlgren Screens After Platelet Impact

TABLE 3. PLATELET HITS BY PANEL NUMBER FOR A 10-DEGREE IMPACT ANGLE

Shot Number	Projectile Impact Velocity (m/s)	Panel Number																						Total Reflected Platelets
		21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64	71	72	73	74	
140	988					2				5					2			4	2	4	1					20
144	988																									0
148	986																	1	1			1	1			4
153	985																						1	1		2
149	984																									0
141	971																									0
157	928					6												7	5	3						21
159	891									1				6					3							10
158	888																	3								3
156	874										1				3	12		2	1	4						23
166	861																									0
164	847					2	1			14				4				1	1	2		1			1	27
171	846																					2				2
162	842													2				6	1							9
163	840									2	4			14	6				1	1	1					29
160	826										1			1				3				1		1	2	9
165	793						1			2								2	1				1			7
168	760					1												3					1			5
170	753					3												2					1			6
180	744					1												3								4
199	735																					1				1
195	731													1	4	1		4	2							12
167	720																	1	1							2
198	695									1				9	3		1		5	2				1		22
200	645	1				2				1	1			2	1				3	1	4	1				17
203	641								1	1				1				2								5
202	634									3									2							5
176	570					1												2		2		1				6
173	566					3	1									1		2	1							8
174	548		2				1								3				4	3	1					14
172	537					2				1																3
179	531													1	3											4
178	524													1	3	7	2	2	2	2						19
186	492					1								4	1			3	9							18
184	483					1												2		1						4
151	471													7	13	4			4							28
181	463					2																				2
183	457																	3	1							4
208	452															1		1	1					2		5
204	449														3	1		2	2	1						9
209	425	1				2											1		1			1				6
206	421																		1				1			2
207	395					3	2			6	1			5												17
222	325														1	6			10	6				5		28
213	321														3	1		5	18	1						28
211	313										X															
212	313					1								10	12			2		1						26
220	313													X												
221	307													X												
210	291													X												

TABLE 4. TABLE OF CALCULATED MAXIMUM/MINIMUM REFLECTED PLATELET VELOCITIES (METERS/SEC)

Shot Number	Projectile Impact Velocity (m/s)	Witness Screen/Zone Number					
		20	30	40	50	60	70
140	988						
144	988						
148	986					863	824
						651	690
153	985						647
							612
149	984						
141	971						
157	928		292			954	
			256			215	
159	891			232	784	718	
				229	634	694	
158	888						
156	874			546	802	831	
				537	336	171	
166	861						
164	847		754	215	213	803	432
			725	209	210	285	391
171	846						
162	842					819	
						87	
163	840			273	789	207	
				251	140	142	
160	826			359		785	151
				353		669	133
165	793					751	612
						722	584
168	760		512			566	
			498			377	
170	753		671				
			504				
180	744					609	
						587	
199	735						121
							116
195	731				627	650	
					429	616	
167	720						
198	695			121	722	634	
				119	139	152	
200	645	87	193	643	618	175	185
		86	187	429	204	140	177

TABLE 4. TABLE OF CALCULATED MAXIMUM/MINIMUM REFLECTED PLATELET VELOCITY (METERS/SEC) (Concluded)

Shot Number	Projectile Impact Velocity (m/s)	Witness Screen/Zone Number					
		20	30	40	50	60	70
203	641		301	522	577	593	
			289	514	569	549	
202	634			519		440	
				512		426	
176	570					532	
						69	
173	566						
174	548						
172	537						
179	531						
178	524				92	428	
					55	73	
186	492				452	293	
					416	96	
184	483		359			431	
			349			408	
151	471				200	417	
					125	381	
181	463		390				
			378				
183	457					283	
						277	
208	452				303	364	
					297	326	
204	449				66	102	
					62	96	
209	425	343	275				
		328	266				
206	421					211	258
						204	246
207	395		291	177	167		
			176	151	160		
222	325				153	261	
					133	106	
213	321				112	244	
					106	77	
211	313			246			
				246			
212	313		239		83	244	
			232		69	230	
220	313				235		
					235		
221	307						
210	291				237		
					237		

SECTION III

CALCULATIONS FOR THE MAXIMUM ALTITUDE AND MAXIMUM HORIZONTAL RANGE OF A REFLECTED PLATELET

The fastest velocity calculated for the 20-degree zone and the 30-degree zone were used as the initial reflected platelet velocity to calculate the greatest altitude and the greatest range obtained by the platelet. The drag coefficients used are for a tumbling platelet.

30 Degrees 816 Meters/Second

Time of Flight (sec)	Platelet Striking Velocity (meters/second)	Altitude (meters)	Horizontal Range (meters)
0.5	67	41	73
1.0	35	52	95
1.5	23	56	108
2.0	18	58	118
2.5	15	56	126
3.0	15	53	133
3.5	15	48	138
4.0	16	42	142
4.5	17	34	146
5.0	18	26	149
5.5	18	17	152
6.0	19	8	154

20 Degrees 945 Meters/Second

Time of Flight (sec)	Platelet Striking Velocity (meters/second)	Altitude (meters)	Horizontal Range (meters)
0.5	68	29	82
1.0	36	36	106
1.5	24	38	120
2.0	19	37	131
2.5	16	35	139
3.0	16	30	146
3.5	16	24	152
4.0	17	17	156
4.5	17	9	160
5.0	18	1	163

Figure 11 illustrates the maximum altitude and range calculated for a 10-degree firing angle.

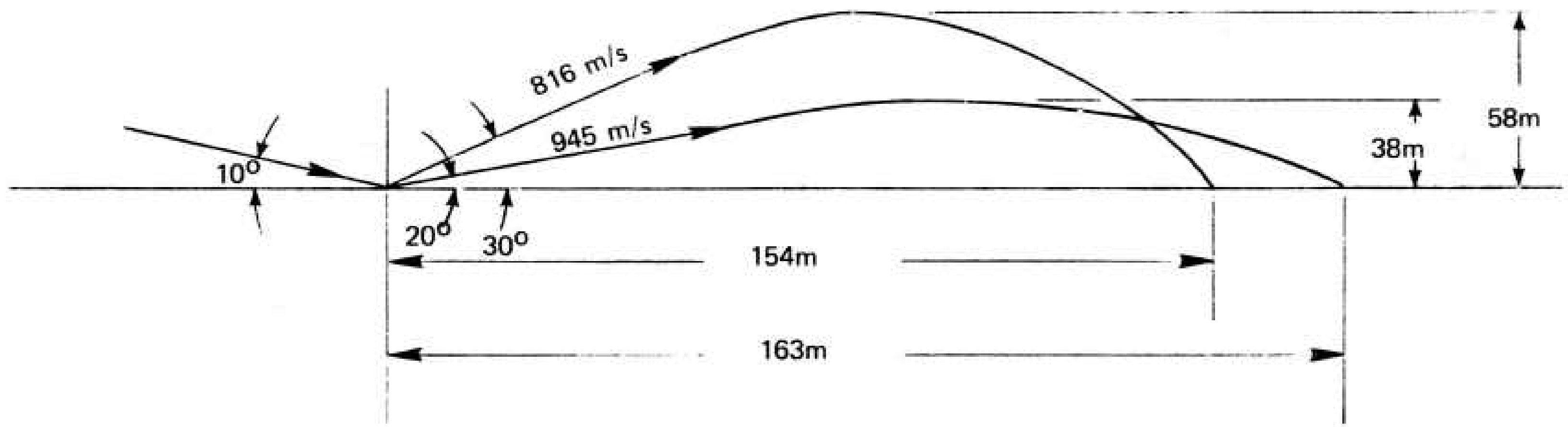


Figure 11. Maximum Altitude and Range from 10° Firing Angle

DRAG COEFFICIENTS FOR A GIVEN PLATELET
MACH NUMBER

Mach Number	Drag Coefficient
0.00	0.8000
0.60	0.8000
0.70	0.8200
0.80	0.8400
0.90	0.8800
1.20	1.2000
1.30	1.3000
1.60	1.3300
2.00	1.2300
3.00	1.1100

SECTION IV

CONCLUSIONS

At incidence impact angles above 20 degrees and impact velocities above 282 meters/second (925 fps), the projectile fragments upon impact with the sand. Only a few platelets were reflected under these conditions. The reflected platelets observed had a reflected vertical angle of less than 10 degrees.

At 10-degree incidence impact angle:

a. At impact velocities above 313 meters/second (1027 fps), the projectile consistently fragments upon impact with the sand.

b. The reflected platelets separate. They are not fuzed together by the impact.

c. No platelets are reflected higher than a vertical angle of 30 degrees.

d. At impact velocities below 313 meters/second, the projectile does not consistently fragment. Non-fragmenting projectiles are reflected intact off the sand target at a vertical angle of less than 10 degrees.

Moisture content of the sand may have some effect on the distribution of the reflected platelets, but it does not appear to affect the total number of reflected platelets for a given shot.

The number of reflected platelets cannot be predicted by knowing the impact velocity.

Based on the assumptions of drag, and maximum and minimum platelet velocities after ground impact, the projectile no longer represents a hazard to the launching aircraft.

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APPENDIX A

VELOCITY CALCULATIONS

The calculated velocity discussed here is only an approximation of the instantaneous velocity of the reflected platelet. The reflected platelet velocities shown in Table 3 are the maximum possible velocity and the minimum possible velocity for the given zone. The time-of-flight data for each zone is shown in Table A-1. The velocity calculations are best described by the following example, using data from Shot Number 164, Zone 60.

From Table A-1 Time-of-Flight (milliseconds)	From Table 3 Panel Number	Number of Hits
4.10	61	1
8.54	62	1
8.76	63	2
10.90	64	0

The longest distance a platelet had to travel was to Panel 63. Assuming the hit was in the most distant corner of Panel 63, the distance from the Break Paper to the corner of Panel 63 in Table A-2 is 3.29 meters. This distance divided by the shortest time-of-flight gives the fastest possible velocity for Zone 60.

$$V_{max} = \frac{3.29 \text{ m}}{4.10 \text{ ms}}$$

$$V_{max} = 803 \text{ meters/second}$$

The shortest distance a platelet had to travel was to Panel 61. Assuming the hit was at the center of this panel, the distance from the Break Paper to the center of Panel 61 shown in Table A-2 is 3.11 meters. This distance divided by the longest time-of-flight gives the slowest possible velocity for Zone 60.

$$V_{min} = \frac{3.11 \text{ m}}{10.90 \text{ ms}}$$

$$V_{min} = 285 \text{ meters/second}$$

TABLE A-1. TIME-OF-FLIGHT OF REFLECTED PLATELETS

Shot Number	Zone Number [Time of Arrival (msec)]							
	10	20	30	40	50	60	70	80
148						3.75	4.25	
						4.78	4.81	
151					15.73	7.76		
					20.65	7.85		
					20.84	8.22		
					20.90			
					20.93			
					21.34			
					21.96			
					22.24			
					23.30			
					24.08			
153							5.16	
							5.81	
156				5.66	3.93	3.96		
					6.26	4.15		
					6.29	9.03		
					6.35	9.65		
					6.67	16.79		
					6.73	16.82		
					6.95	18.11		
					7.04	18.18		
					7.39			
					7.61			
					9.03			
157			10.97[a]			3.45		
			11.88[a]			4.14		
			12.16			4.29		
						7.81		
						8.09		
						8.12		
						9.12		
						9.44[a]		
						9.50[a]		
						9.56		
						9.78		
						14.39		
						14.45		
158						3.88		
						3.94		
						4.98		

TABLE A-1. TIME-OF-FLIGHT OF REFLECTED PLATELETS (Continued)

Shot Number	Zone Number [Time of Arrival (msec)]							
	10	20	30	40	50	60	70	80
159				13.17	3.90[a] 3.97 4.63 4.73	4.51		
160				8.61		4.08 4.43 4.65	24.30 24.75 24.91	
162						3.95 4.80 4.92 35.83 35.86		
163				11.32 11.60[a] 12.01[a]	3.92 3.95 4.01[a] 4.80 4.89 9.50[b] 9.53[a] 9.78[a] 9.91 10.03 10.13 11.58 19.34 21.47[a] 21.54	16.46 22.07[a]		
164			4.29	14.22 14.41 14.44	14.38	4.10 8.54 8.76 10.90	8.48	
165						4.31[a]	5.72	
168			6.25			5.66 6.94 8.25		
170			4.77 4.95 6.17				11.74	
176			8.34			7.65	18.40	

TABLE A-1. TIME-OF-FLIGHT OF REFLECTED PLATELETS (Continued)

Shot Number	Zone Number [Time of Arrival (msec)]							
	10	20	30	40	50	60	70	80
178					35.48	7.69		
					35.61	8.60		
					36.26	36.88		
					36.32	42.37		
					38.94	42.40		
					47.98	42.46		
					49.60			
					49.84			
					50.00			
					53.27			
					53.30			
					53.49			
					54.30			
					55.08			
180						5.26[a]		
						5.30		
181			7.72					
			8.22					
183						8.44		
						8.97		
						11.22		
184			8.91			7.63[a]		
186					6.84	11.03[a]		
					7.16	11.72[a]		
					7.25	12.44[a]		
						26.16		
						32.19		
						32.38		
195					5.02	4.98		
					5.42	5.05		
					6.25			
					6.28			
					7.03[a]			
198				25.34	4.53	5.19		
					4.60	20.59		
					4.69			
					16.93			
					17.08			
					17.17			
					17.39			
					19.07			
					20.81			
					21.74			

TABLE A-1. TIME-OF-FLIGHT OF REFLECTED PLATELETS (Continued)

Shot Number	Zone Number [Time of Arrival (msec)]							
	10	20	30	40	50	60	70	80
199							28.59	
200		40.50	16.61	4.81	4.88	17.86	18.79	
				7.02	5.22	18.79		
					14.78	19.78		
						19.81		
						21.74		
						22.55		
						22.67		
						24.29		
202				5.89		7.36		
203			11.31	5.86	5.30	5.40		
						5.67		
204					47.38	32.24		
					48.35	32.30		
					48.88			
206						15.33	13.58	
207			11.36	17.49	18.36			
			11.52	17.62	18.48			
			17.55	17.86	18.82			
			17.59	17.89				
			17.68	17.96				
				19.57				
				20.00				
208					10.40	8.89		
						9.54		
209		10.12	11.65					
			11.68					
212			13.38		37.38	13.50		
					41.91			
					43.51			
213					28.17	13.67		
					28.54	14.20		
					28.58	14.26		
					28.61	14.38		
						14.42		
						28.40		
						29.71		
						29.90		
						30.37		
						30.46		

TABLE A-1. TIME OF FLIGHT OF REFLECTED PLATELETS (Concluded)

Shot Number	Zone Number [Time of Arrival (msec)]							
	10	20	30	40	50	60	70	80
213 (continued)						36.38 37.46 38.61 38.64 40.25		
222					20.59 20.66 22.88[b]	12.59 12.75 13.38 21.72 22.50 24.28 25.31 29.22 29.28		

[a]Duplicate Time
[b]Triplicate Time

TABLE A-2. DISTANCE FROM BREAK PAPER TO CENTER AND CORNER OF EACH PANEL OF THE DALHGREN WITNESS SCREENS

Panel Number	Distance from Break Paper to Center (meters)	Distance from Break Paper to Most Distant Corner (meters)
21 & 71	3.32	3.47
22 & 72	3.34	3.50
23 & 73	3.38	3.55
24 & 74	3.46	3.66
31 & 61	3.11	3.20
32 & 62	3.13	3.24
33 & 63	3.18	3.29
34 & 64	3.26	3.41
41 & 51	3.01	3.06
42 & 52	3.04	3.92
43 & 53	3.08	3.15
45 & 54	3.17	3.27

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INITIAL DISTRIBUTION

USAF/RDQRM	2
USAF/XOXFCM	1
USAF/XOOWA	2
AFSC/IGFG	1
AFSC/SDWM	1
AFSC/DLCAW	1
AFML/DO/AMIC	1
4950 Test W/TZHM	1
AFIT/LD	1
ASD/YEM	10
ASD/ENAZ	1
AFFDC/PTS	1
TAC/DRA	1
SAC/LGWC	1
SAC (NRI/STINFO Lib)	1
WRAMA/MMEBL	1
CIA, CRE/ADD/Publications	2
AFWL/LR	1
AUL/AUL-LSE-70-239	1
Redstone Science Info Cntr, Doc Sec	2
Rock Island Arsenal/SAPRI-LW-A	1
USA Mat Sys Anlys Agncy, AMXSY-DD	1
USA Mat Sys Anlys Agncy, AMXSY-A	1
USA Aberdeen R&D Cntr, AMXBR-TB	1
Frankford Arsenal, Lib, K2400	1
Picatinny Arsenal, SARPA-TS	1
USN Wpns Lab, William A. Kemper 9X	1
USN Nav Ord Lab, Tech Lib	2
Nav Ord Stn, Tech Lib	1
CO, Nav Wpns Stn/20323	1
Nav Sys Cntr, New Port Lab/Tech Lib	1
USN Wea Cntr/Code 533/Tech Lib	2
USNWC/Code 4565	1
AFWL/Tech Lib	1
NASC/Code AIR-5323	1
Office Nav Research/Code 473	1
NASA STINFO Fac, Acquisitions Br	1
Los Alamos Science Lab/Report Lib	1
Battelle Memorial Inst/Report Lib	1
Inst for Defense Analysis, Classified Lib	1
Sandia Lab, W. H. Curry Div 5625	2
The Rand Corp/Lib-D	1
Harry Diamond Labs/AMXDP-TC	1
DDC/TC	2
USAFTFWC/TA	1
CO, Nav Wpns Lab	1
CO, Watervliet Arsenal/SARWV-RDT-L	1
Plastec-Bldg 176, Picatinny Arsenal	1
NWC/Code 51102	1
Ogden ALC/MMNOP	2
AF Spec Comm Cntr/SUR	2
Dept of the Army/DAMA-WSA	1
Picatinny Arsenal/SARPA-FR-S-A	1
USA Mat Sys Analysis Agncy/AMXSY-DS	1
USA Mat Command/AMCRD-WN	1
Nav Wpns Eval Fac/Code WE	1
Ofc of Ch of Nav Opns/OP-982E	1
Nav Research Lab/Code 2627	1
USAFTAWC/AY	1
TAWC/TRADOCLO	1
AFATL/DL	1
AFATL/DLB	1
AFATL/DLY	1
AFATL/DLOU	1
AFATL/DLOSL	2
AFATL/DLYV	1
AFATL/DLDL	1
AFATL/DLDA	1
ADTC/WE	1
AFATL/DLDG	10
AFRDPA, Rm 5D282	1
USAF (AF/SAMI)	1
ASD/ENFEA	1
ASD/ENYEHM	1
AFIS/INTA	1
AFATL/DLDD	1

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